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CHANGING WHAT'S POSSIBLE

Application of Plasma-Window Technology to Enable an Ultra-High-Flux DT Neutron Source

GAMOW Kickoff Meeting
January 21–22, 2021

Ross Radel, PhD, PI -- Phoenix, LLC
Sub-awardees/Consultants – MIT, UW Madison, Brookhaven NL

U.S. DEPARTMENT OF ENERGY

Team members and roles

Phoenix Team

- Dr Ross Radel
  - Principal Investigator
- Dr Tye Gribb
  - Senior Scientist
  - Beam optics, plasma surface interactions
- Preston Barrows
  - Lead plasma physicist
  - Physics package design and modelling
- Todd Kile
  - Lead electrical engineer
  - Electrical modelling and design
- Jin Lee
  - Lead mechanical engineer
  - Mechanical design and thermal modelling

Sub-awardees/Consultants

- Dr Ady Hershcovitch
  - Brookhaven National Lab
  - Plasma window inventor
  - Design consultant for plasma window technology
- Dr Gerald Kulcinski
  - University of WI (Emeritus)
  - Application consultant with a focus on fusion technology
- Dr Michael Short
  - Mass. Institute of Technology
  - Application consultant with a focus on materials irradiation

High-level motivation, innovation, and goals of the project (how will your project better enable commercially viable fusion energy?)

- *Motivation*
  - *Support the development of fusion reactor materials and systems by providing an intense source of DT neutrons for irradiation testing*
- *Project Impact*
  - *With Plasma Windows integrated into each beam of a multi-beam DT gas target neutron generator, an instrument can be fielded in 5 years providing fusion-reactor-level displacements per atom (dpa) for the qualification of fusion materials.*
  - *Provides value to fusion technology developers every step of the way*
- *Project Summary*
  - *Optimize previously developed Plasma Window (PW) technology from Brookhaven National Lab and integrate it with a commercial Phoenix gas target neutron generator to increase target gas pressure and demonstrate transformative increase in neutron yield per beamline.*

- GAMOW Project Goal
  - *Deliver a Plasma Window prototype demonstration of steady-state operation with an aperture diameter of 2 cm, L/D of under 10, and a deuterium target chamber pressure of at least 400 Torr*

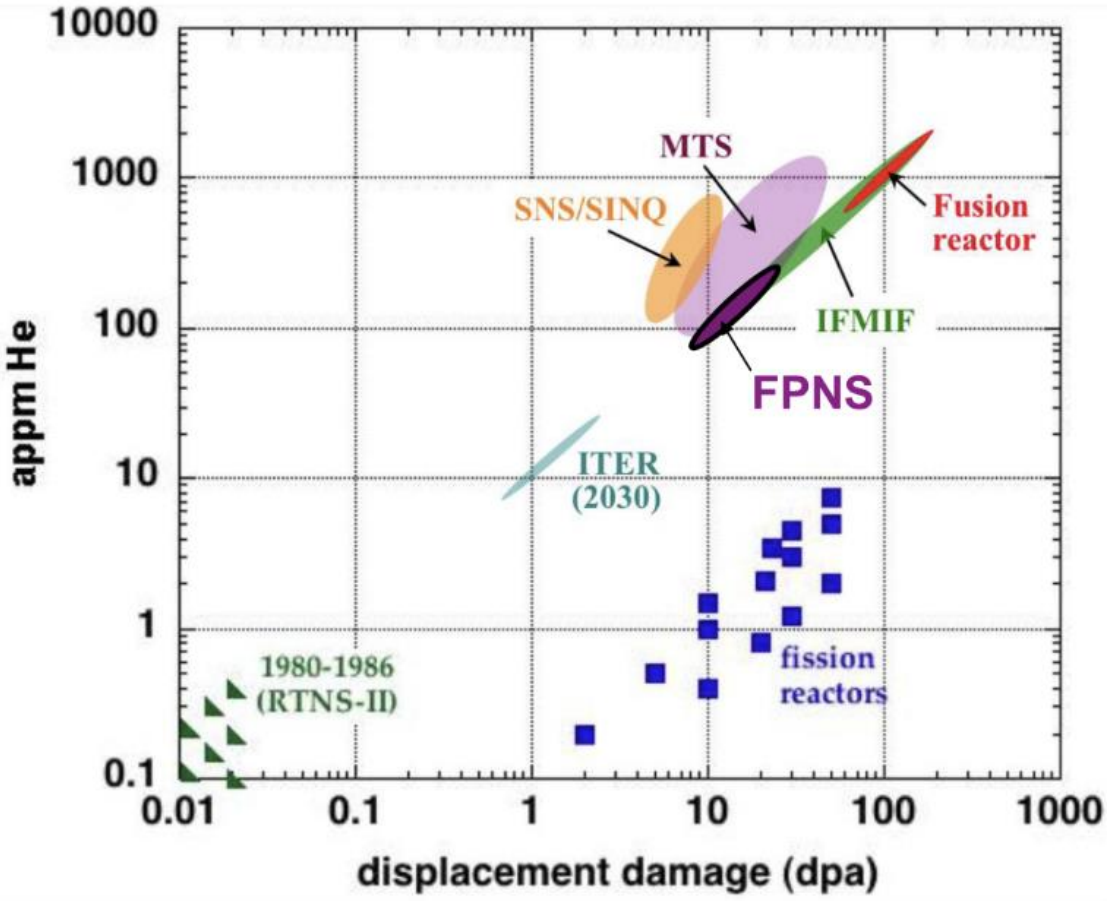


Figure adapted from FESAC Report DOE/SC-0149, February 2012

Major tasks, milestones, risks, and desired project outcomes (include aspirational quantitative metrics to be achieved)

Task 1: Design of Scalable Plasma Window (Q1→ Q2)

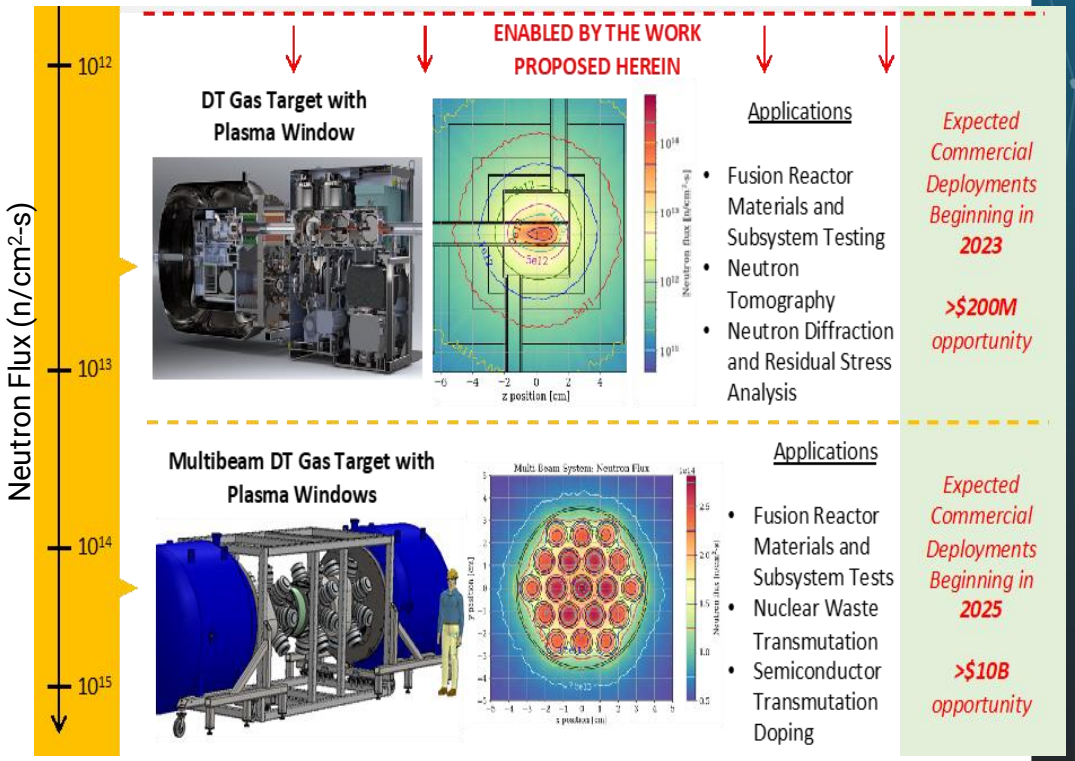
- Design Analysis
  - Document in quarterly report a plasma-physics analysis to identify the expected scaling and desired ranges of key operational parameters including aperture diameter, cathode current and voltage, and target pressure
  - **Key Risk:** Scalability. For peak utility, the plasma window must be scaled to diameters of 1-2 cm, larger than have generally been demonstrated. Scaling laws and performance previously demonstrated with smaller diameter systems may not extend to the desired larger diameter range
- Thermal Analysis
  - Document in quarterly report the thermal modeling effort
  - **Key Risk**: Insufficient cooling of the anodes, cathodes, or cooling plates will result in component damage and loss of functionality over time
- Design Review
  - Final Design Review (FDR) for the plasma window prototype will be presented to a panel assembled by Phoenix. Phoenix to demonstrate that the plasma window prototype design can achieve a target chamber pressure of at least 400 Torr deuterium with a 2 cm diameter aperture and L/D under 10

Task 2: Plasma Window Lab Demo / Optimization (Q3 → Q7)

- Primary Assembly Complete
  - Core subsystems of plasma window prototype assembled and tested
  - **Go/No Go Milestone** (end of Q4)
- Final Assembly Complete
  - Baseline plasma window prototype fully assembled in a configuration with a 0.5 cm diameter aperture, L/D of <10
- Plasma Window Full Demonstration
  - Plasma window prototype steady-state operation demonstrated with an aperture diameter of 2 cm, L/D of under 10, and a deuterium target chamber pressure of at least 400 Torr. This pressure corresponds to the desired tritium gas pressure of 700 Torr anticipated for the same hardware configuration and with beam pumping present during future accelerator operation
  - Design will be accounting for target cooling considerations and tritium usage to enable faster integration

Additional Tasks

- Tech-to-Market (T2M) Plan Development (Q2 → Q7)
- Presentations and Publications (Q4 → Q8)

T2M and aspirational follow-on plans

- Phoenix is pursuing a phased approach to increase the available DT neutron flux
  - Single beam variation of Phoenix core systems with a Plasma Window
  - Multiple-beam variation of Phoenix systems with Plasma Windows
- Proposed techno-economic metrics of ARPA-enabled Multi-Beam System with Plasma Windows
  - DT irradiation capability of >10 dpy/year
  - Fully outfitted facility cost < $50M
    - Includes facility, neutron source, tritium handling, and hot cell (no instruments)
    - Cost assumes project is managed, licensed, and built privately
  - First neutrons in < 60 months
- Phoenix will be exploring deployment options (private, PPP, subcontracting to Nat Lab, etc)